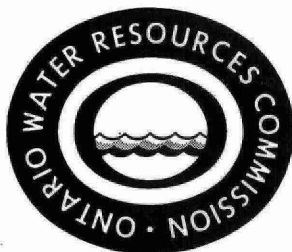


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R2028



REMOVAL OF
SYNTHETIC ANIONIC DETERGENTS
BY THE
ACTIVATED SLUDGE PROCESS



DIVISION OF RESEARCH
ONTARIO WATER RESOURCES COMMISSION

May, 1971

R.P. 2028

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REMOVAL OF
SYNTHETIC ANIONIC DETERGENTS
BY THE
ACTIVATED SLUDGE PROCESS

By
A. V. Giffen
May, 1971

Division of Research
Paper No. 2028

Ontario Water Resources Commission
135 St. Clair Avenue West
Toronto 7, Ontario

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INTRODUCTION

Synthetic anionic detergents were first introduced as specialty items for commercial and household consumption during the mid 1930's. By 1950 the detergent market was 80 percent soap and 20 percent synthetic detergent; today over 80 percent of the cleaning compounds in use in Canada are synthetic anionic detergents. The use of anionic detergents in Canada amounts to approximately 18 pounds per capita per year.

The principal surface active compound (surfactant) used in anionic detergents is the sodium salt of alkyl benzene sulphonate. The alkyl benzenes, or alkylates, may be made from either branched hydrocarbon chains or straight hydrocarbon chains. The sulphonates prepared from these groups are designated as Alkyl Benzene Sulphonate (ABS), and Linear Alkylate Sulphonate (LAS).

The alkyl benzenes used almost exclusively for many years in commercial anionic detergents were prepared from branched chain hydrocarbons. The simplified molecular structure is shown in Figure 1a. These materials were referred to as biologically "hard" because they are not readily or completely broken down by sewage micro-organisms. This problem was evidenced by excessive foaming at sewage treatment plants, particularly where the activated sludge process was operated, and on rivers and streams to

which the effluents were discharged. It was established that this foaming was largely due to the presence of unchanged alkyl benzene sulphonates, both in the aeration tanks at the sewage treatment plant and in the effluents flowing into receiving streams.

In response to public dissatisfaction with its product, the detergent industry initiated a large number of studies (1), (2), (3), (4), (5), (6), (7), both in research aimed at defining the problem, and in research directed towards developing anionic materials amenable to biological degradation. During the period from 1951 to 1963 the detergent industry invested over 150 million dollars in research, development, and new process equipment which ultimately led to the production of a new biodegradable anionic detergent to replace ABS. Hammerton (8) was among the first to demonstrate that for the material most widely used - ABS - the degree of removal by biological action (biodegradability) was influenced by the structure of the alkyl chain. By 1963 it was generally accepted that by using relatively unbranched side chains in the form of LAS the biodegradability was greatly increased, and such materials became known as biologically "soft" anionic detergents. The simplified molecular structure is shown in Figure 1b.

In 1964 the manufacturers of anionic detergents announced

their intention of converting production from biologically "hard" to "soft" surfactants. On March 31, 1967, the changeover in Canada from ABS to LAS materials was complete. The purpose of this study was to determine the effectiveness of the changeover from ABS to LAS on the removal efficiencies through the activated sludge process, and to determine the factors affecting the efficiency of removal.

DETERMINATION OF ANIONIC DETERGENT

The method of analysis used for the determination of anionic surfactants is the methylene blue method as described in "Standard Methods for the Examination of Water and Wastewater", 11th and 12th editions. This is the most widely used technique for the quantitative measurement of anionic surfactants, but it does not differentiate between ABS, LAS and other methylene blue, chloroform-extractable substances, man-made or natural. (9) For this reason, the results of this study have been expressed only in terms of methylene blue active substances (MBAS).

RESULTS

The plants selected for the study are listed in Table I. At least once each month biochemical oxygen demand (BOD), suspended solids (SS), and MBAS analyses are performed on samples of raw sewage and final effluent from each plant included in the study. This allowed an estimate of the general efficiency of the plants, and established a history of the concentration of MBAS reaching the plants in the raw sewage and discharged in the final effluent.

Plant operations covered by this report began in January, 1966 and extended through June 30, 1970. The total study is divided into two operational periods based on the type of surfactant product being marketed (ABS or LAS). March 31, 1967, has been taken as the completion date for the changeover from ABS to LAS based on production and marketing projections made by the detergent industry.

The concentrations of MBAS in raw sewage and final effluents before and after the changeover from ABS to LAS surfactant are presented in Table II. The concentrations of BOD and suspended solids in raw sewage and final effluents are represented by quarterly averages in Tables III and IV. Table V summarizes, for the various plants included in the study, the average MBAS removal,

the average suspended solids removal, and the average BOD removal, in addition to the average daily flow, the average aeration period in hours, and the average aeration tank mixed liquor suspended solids (MLSS) in milligrams per litre (mg/l). This data is condensed in bar graph form in Figure 2, indicating percent removal for all three parameters, BOD, suspended solids, and MBAS. Results for quarterly averages for MBAS in the raw sewage and final effluents are shown in Figure 3.

DISCUSSION

The concentrations of MBAS shown in Table II for the raw sewages from before and after the changeover from ABS to LAS products were examined statistically to determine whether or not their means are significantly different, at the 5 percent significance level, using the two-tailed "Student's - t" distribution test. Four of the plants studied, Burlington-Skyway, South Peel-Lakeview, Richmond Hill, and Stratford, showed significantly lower concentrations of MBAS in the raw sewage samples. This reduction cannot be accounted for by a decrease in the sales of anionic detergents. There is the possibility that LAS products were degrading in the sewers as the wastes were being transported to the WPCP. The final effluent MBAS concentrations for all of the plants (Table II) were statistically significantly lower after the changeover.

As shown in Table V and Figure 2 MBAS removal efficiencies cannot be correlated with specific BOD removal efficiencies at any of the plants. There are probably several reasons for this. One of the principal reasons is that calculations of percent removal efficiencies are very dependent on loadings and are not completely reliable at high concentrations or at low concentrations. This is demonstrated in the high MBAS removals reported for Kingston Twp. (Table V) where the mean influent MBAS concentration after the

changeover was 9.2 mg/l (Table II) while during the same period lower MBAS removals were reported for Waterloo (Table V). The final effluent concentration of MBAS reported for Kingston Twp. and Waterloo, however, were essentially the same, 0.6 mg/l and 0.8 mg/l, respectively (Table II).

The removals of MBAS are generally lower than the BOD removals. The unit efficiency through the aeration process could not be calculated because primary effluent samples were not analyzed for MBAS. The removals reported in Table V and summarized in bar graph form in Figure 2 are calculated from raw sewage to final effluent. The particulate and colloidal BOD and a large portion of the suspended solids will be removed with the primary and waste sludge and not require oxidation. However, the soluble BOD and the MBAS which is essentially a soluble component, will tend to pass through the sewage treatment plant; in which case parameters that will exert the greatest influence on the efficiency of BOD and MBAS removal include the following: (a) loadings applied; (b) period of aeration; and (c) biological solids concentration in the aeration tank. Within the range of normal operation the dissolved oxygen concentration in the aeration tank mixed liquor should not affect the efficiency of BOD and MBAS removals. If the system becomes anaerobic, an immediate decrease in efficiency would result.

The data collected from the twelve plants studied were subjected to several statistical treatments. Analysis of variance and multiple correlation and regression techniques were utilized to examine the relationships among aeration time, mixed liquor suspended solids, and MBAS concentration among raw sewage, mixed liquor, and final effluent samples. No statistically significant correlations have been demonstrated. However, it was generally found that, for long aeration periods and high MLSS concentrations, the final effluent MBAS values are less than 1.0 mg/l. Also, for short aeration periods and low MLSS concentrations, the MBAS values in the final effluent samples are greater than 1.0 mg/l (Table V).

The percent removal of MBAS was calculated to determine if any of the plants showed a consistent trend. Eleven of the twelve plants studied showed significantly higher efficiencies as time progressed. The general pattern of MBAS removal through the Burlington-Skyway plant is not as noticeable though, because of the comparatively high removals reported before the change-over (Table V and Figure 2). Two of the plants, South Peel-Lakeview and North Bay, normally operate over design hydraulic load and carry low MLSS in the aeration tanks; as would be expected these plants are less efficient in overall oxidation (Tables III and V).

The general efficiency of each of the plants in removing BOD can be seen in Tables III and V. In order of decreasing consistent efficiency they are Stratford, Burlington-Drury Lane, Burlington-Skyway, Kingston Twp., Kitchener, Waterloo, Burlington-Elizabeth Gardens, Port Colborne-East, Port Colborne-West, Richmond Hill, South Peel-Lakeview, and North Bay. This was expected based on the design data shown in Table I, and the summary of the plant operating data reported in Table V. In general the pattern of MBAS removal follows the BOD removal efficiencies; the plants most effective in BOD removal also were most effective in MBAS removal.

The projected March 31, 1967 transition point is substantiated by the results of the analyses on the final effluents from the plants. Figure 3 shows the results of the sets of quarterly data split at the first quarter of 1967. All of the plants show a reduced concentration of MBAS in final effluents after this date.

SUMMARY AND CONCLUSIONS

A survey has been carried out on twelve municipal WPCP covering a period of four and one half years to determine the effect of the changeover from biologically "hard" ABS surfactants to the more biodegradable LAS surfactants on the removal effectiveness of methylene blue active substances through the activated sludge process. The following observations summarize the results of the study:

1. Final effluent concentrations of MBAS from the activated sludge process were less than 2 mg/l after the changeover to the use of LAS-based products.

2. Final effluent concentrations of MBAS from activated sludge plants operating at or below design conditions were less than 1 mg/l after the changeover.

3. There is some evidence that LAS products may undergo partial degradation in the sewerage systems that lead to the sewage treatment plant.

4. A general relationship existed between the removal efficiency of LAS materials and the removal efficiency of BOD.

5. The degree of MBAS removal is closely related to the aeration time and the concentration of suspended solids in the aeration tank.

The results of this study indicate that the changeover from ABS to LAS based detergents has led to a significant lowering of surfactant concentrations in final effluents from activated sludge type plants. Specifically, they indicate that the changeover does not obviate the need for a high degree of sewage treatment in that high surfactant removals are obtained only when the sewage treatment plant was operated efficiently.

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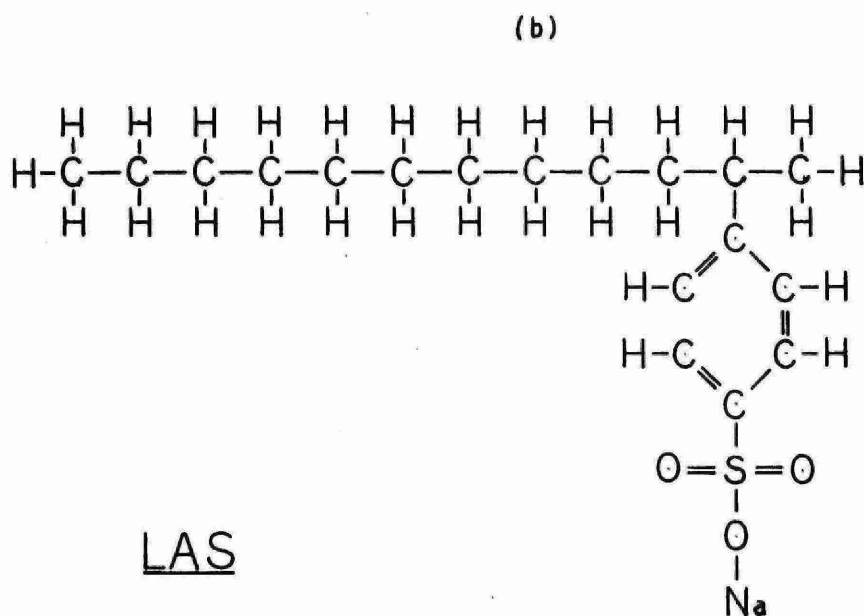
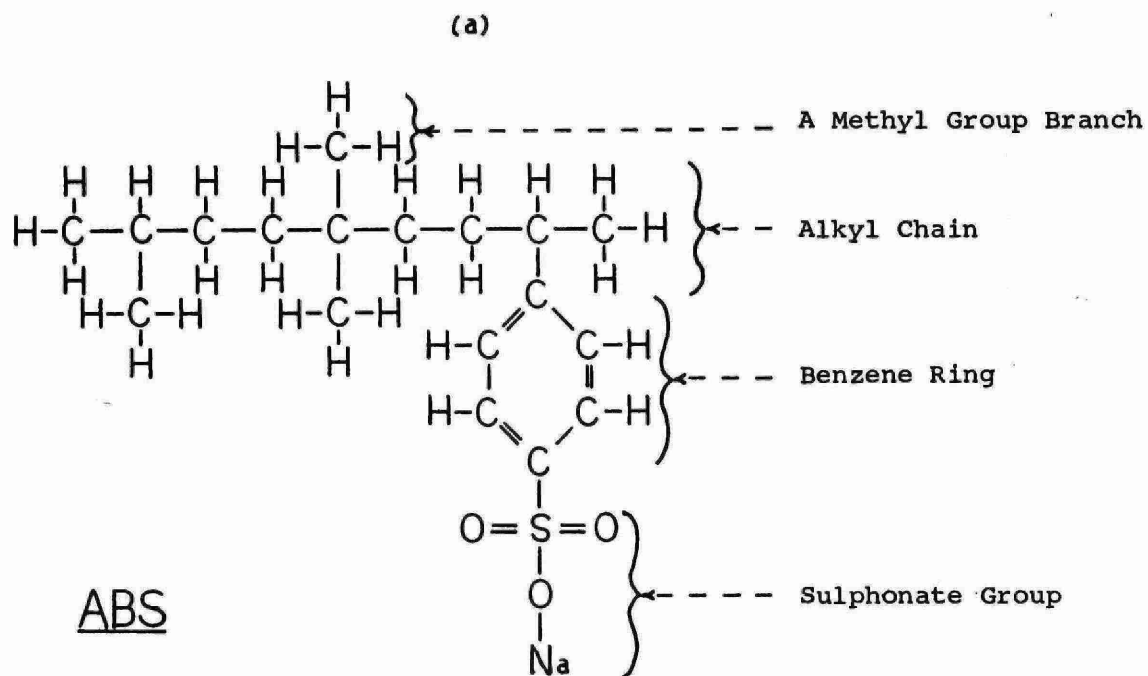
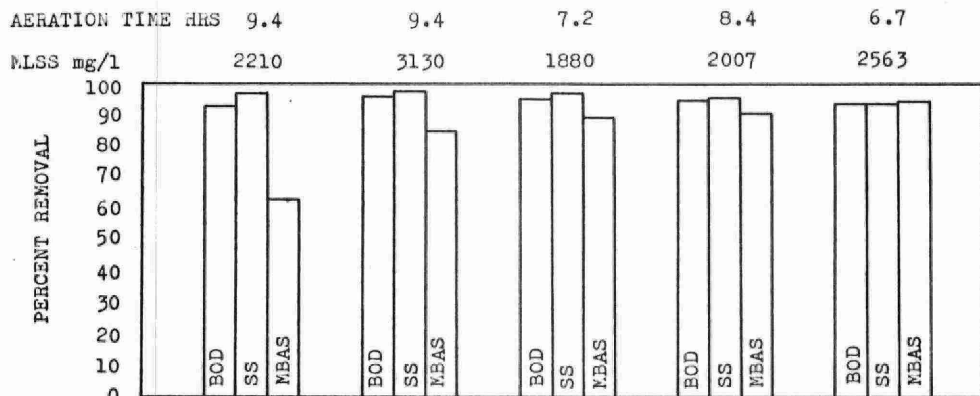


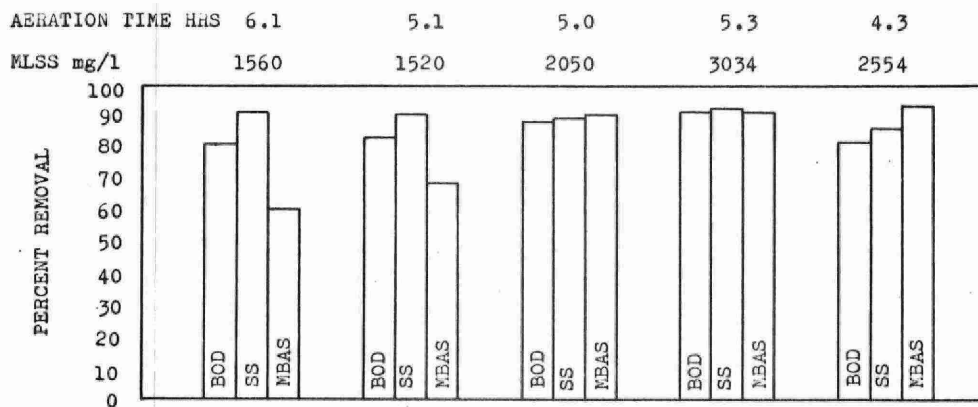
Figure 1. SIMPLIFIED MOLECULAR STRUCTURE FOR ABS AND LAS SURFACTANTS.

(a)

- 16 -

BURLINGTON DRURY LANE

(b)

BURLINGTON ELIZABETH GARDENS

(c)

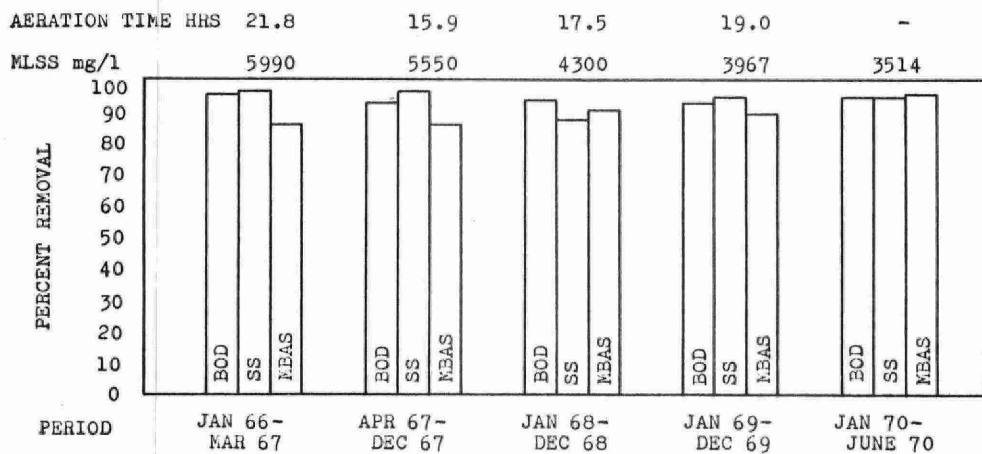
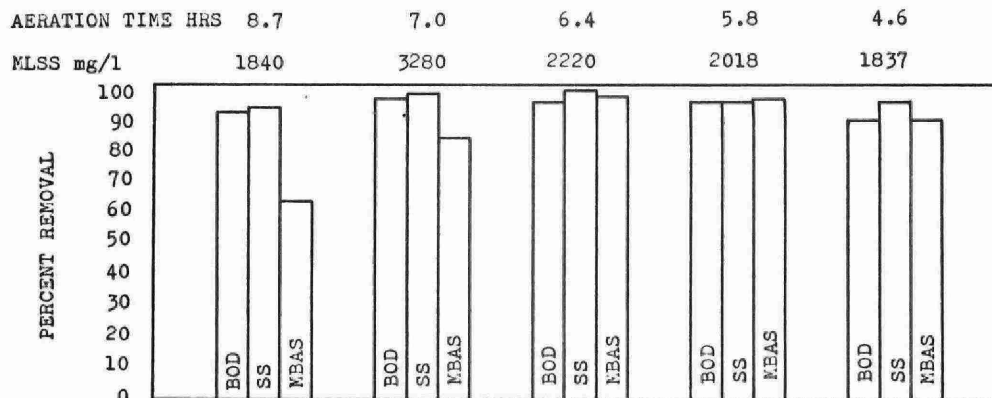
BURLINGTON SKYWAY

FIGURE 2. COMPARATIVE SURFACTANT - BOD AND SS REDUCTIONS.

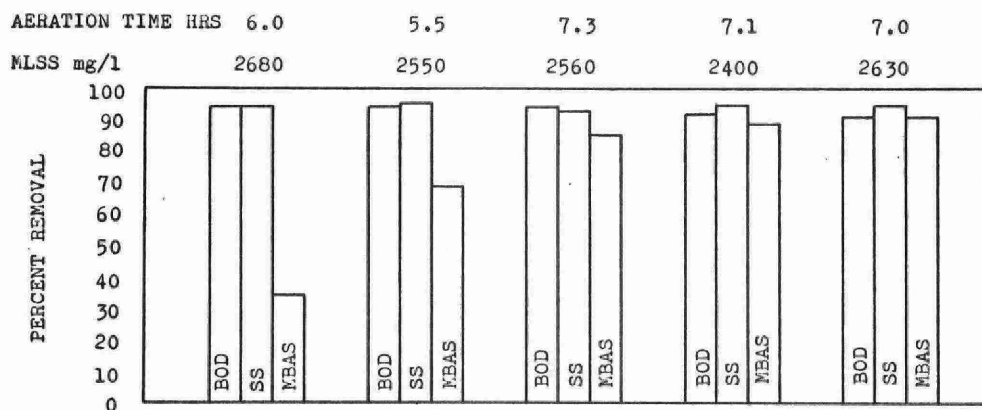
cont....

(d)

- 17 -

KINGSTON TWP.

(e)

KITCHENER

(f)

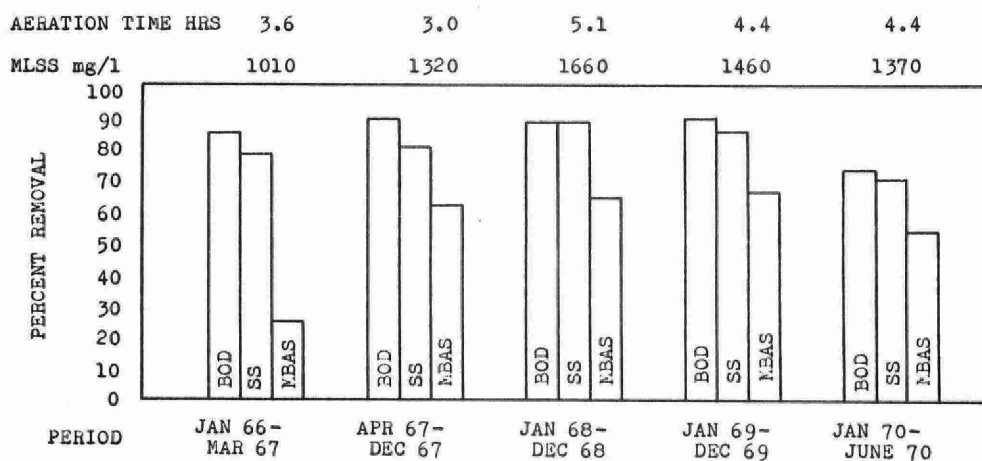
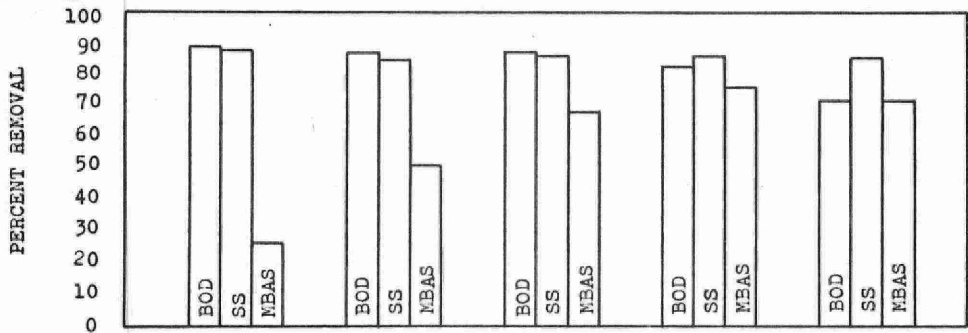
SOUTH PEEL - LAKEVIEW

FIGURE 2. COMPARATIVE SURFACTANT - BOD AND SS REDUCTIONS.

cont....

NORTH BAY

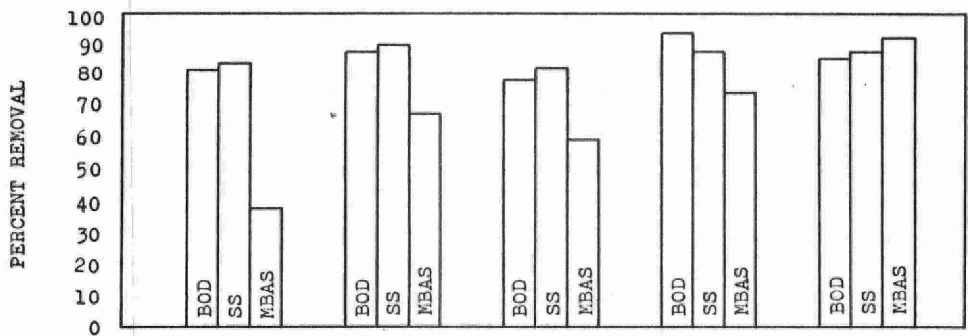
AERATION TIME HRS	5.4	5.6	5.2	4.1	3.9
MLSS mg/l	1200	890	1270	1360	1350



(h)

PORT COLBORNE - EAST

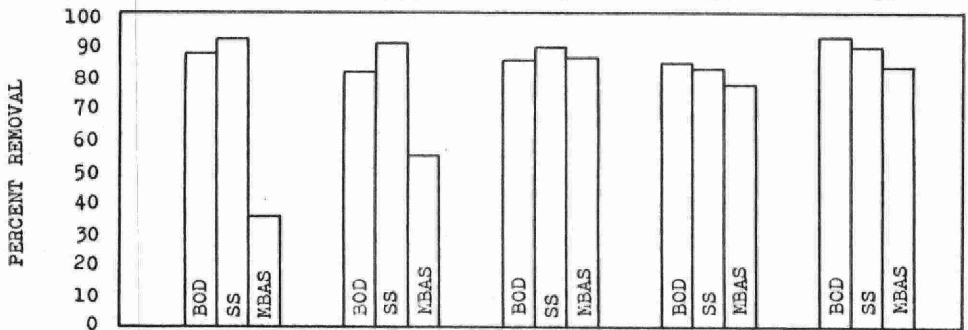
AERATION TIME HRS	5.5	4.6	3.7	3.5	3.2
MLSS mg/l	2500	2380	2220	2756	2290



(i)

PORT COLBORNE - WEST

AERATION TIME HRS	6.4	6.0	5.5	5.5	5.3
MLSS mg/l	1290	1550	1450	1580	1150



PERIOD	JAN 66- MAR 67	APR 67- DEC 67	JAN 68- DEC 68	JAN 69- DEC 69	JAN 70- JUNE 70
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FIGURE 2. COMPARATIVE SURFACTANT - BOD AND SS REDUCTIONS

cont....

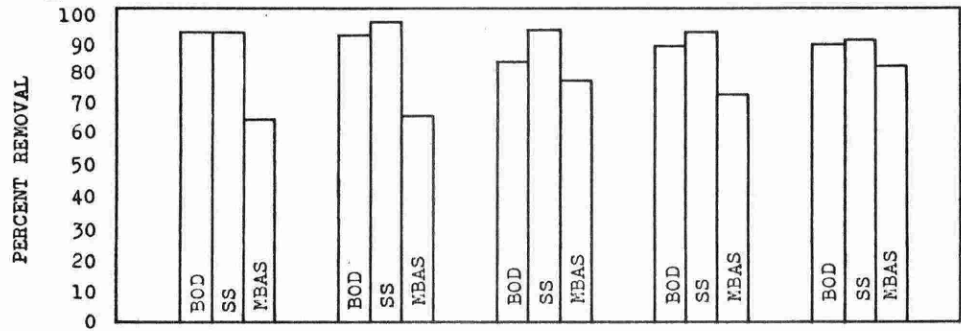
(j)

- 19 -

RICHMOND HILL

AERATION TIME HRS 5.5 5.5 4.8 4.7 4.4

MLSS mg/l 1840 1480 960 1130 1260

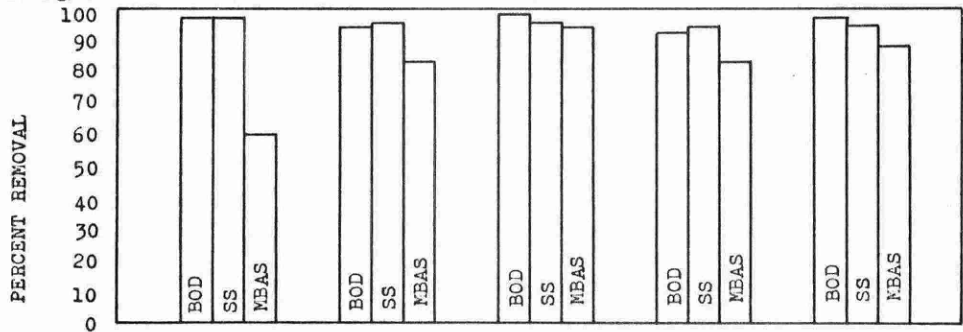


(k)

STRAITFORD

AERATION TIME HRS 6.2 4.9 5.6 5.9 5.4

MLSS mg/l 2330 2320 2350 2340 2070



(l)

WATERLOO

AERATION TIME HRS 8.8 7.1 7.1 5.1 5.7

MLSS mg/l 2320 2310 2760 2530 2720

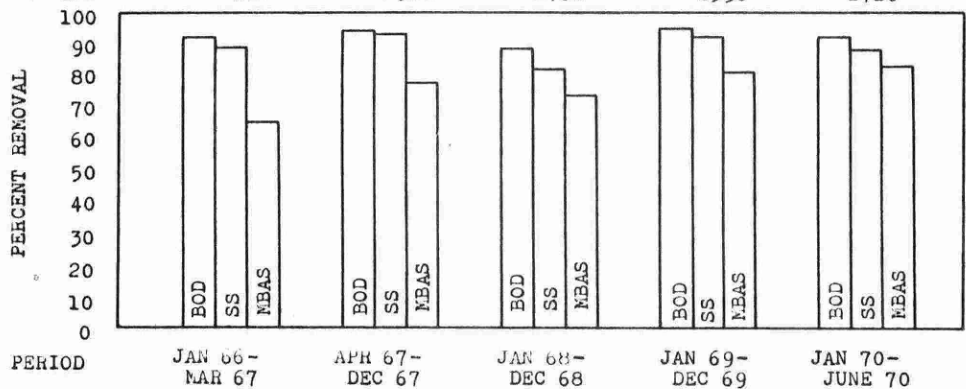
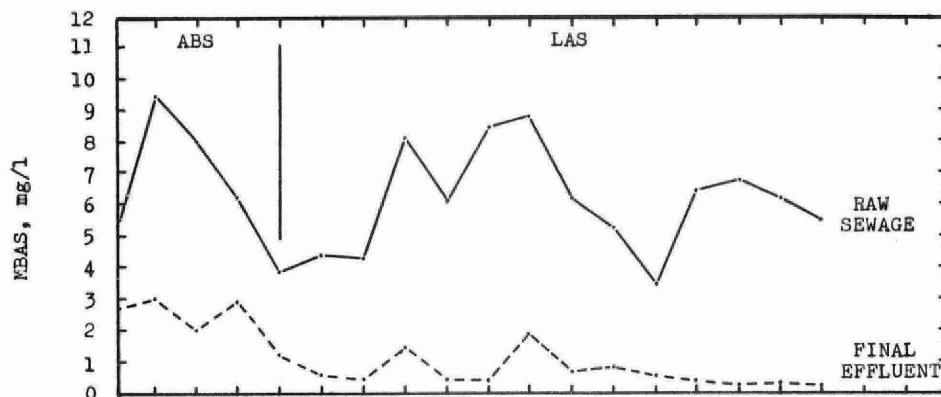


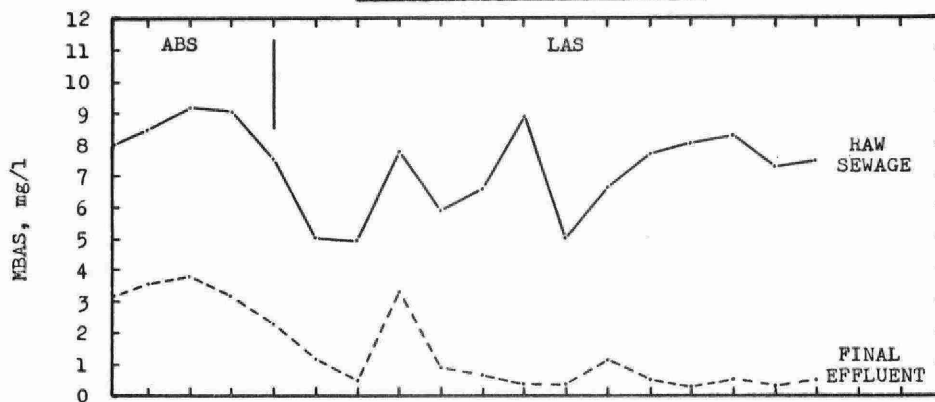
FIGURE 2. COMPARATIVE SURFACTANT - BOD AND SS REDUCTIONS.

(a)

- 20 -

BURLINGTON DRURY LANE

(b)

BURLINGTON ELIZABETH GARDENS

(c)

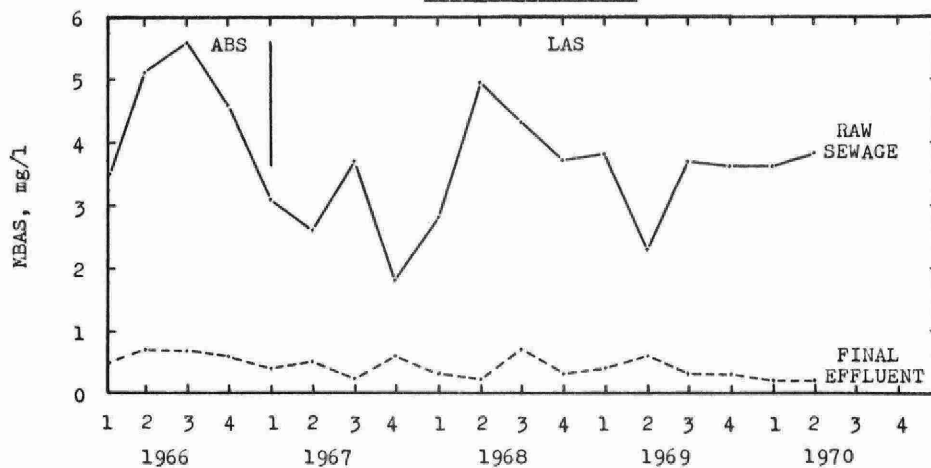
BURLINGTON SKYWAY

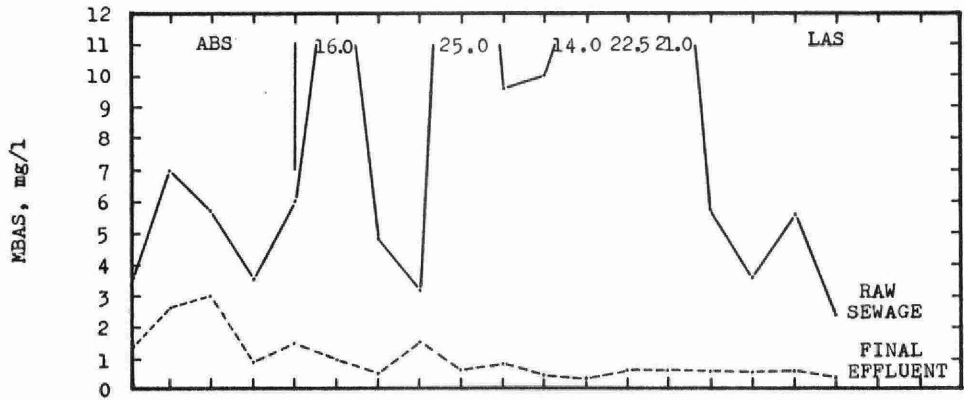
FIGURE 3. QUARTERLY MBAS CONCENTRATIONS IN RAW SEWAGE AND FINAL EFFLUENT

Cont....

(d)

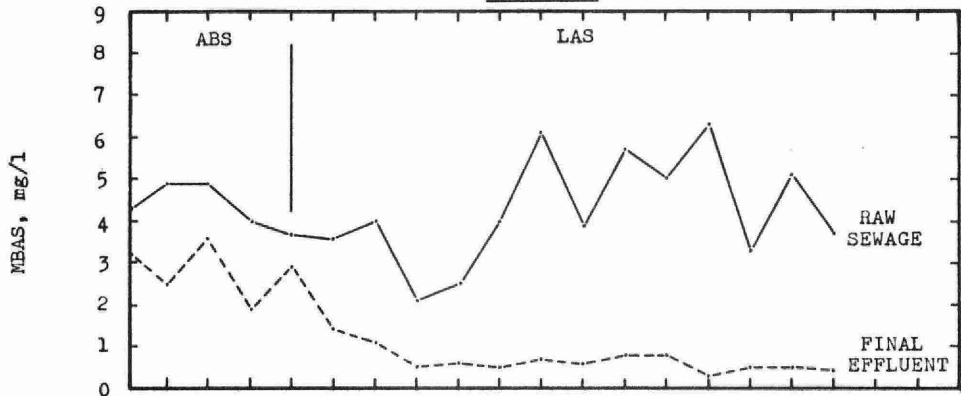
- 21 -

KINGSTON TWP.



(e)

KITCHENER



(f)

SOUTH PEEL - LAKEVIEW

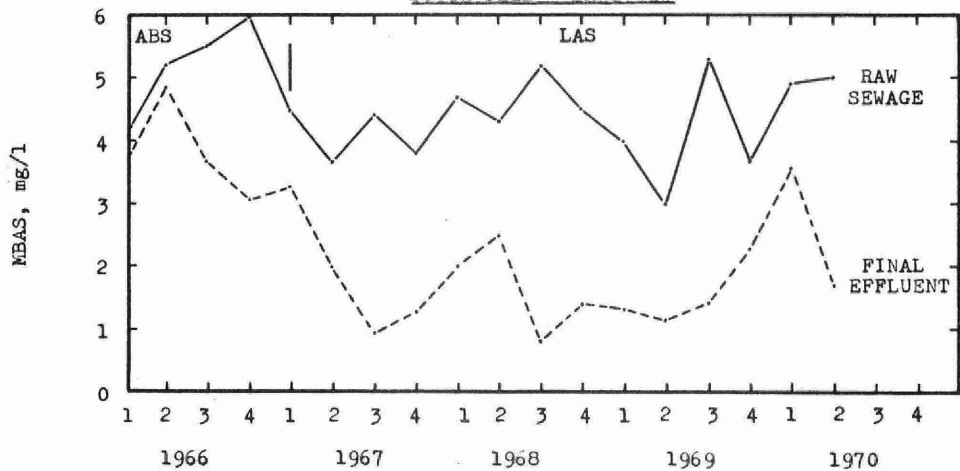


FIGURE 3. QUARTERLY MBAS CONCENTRATIONS IN RAW SEWAGE
AND FINAL EFFLUENT

Cont....

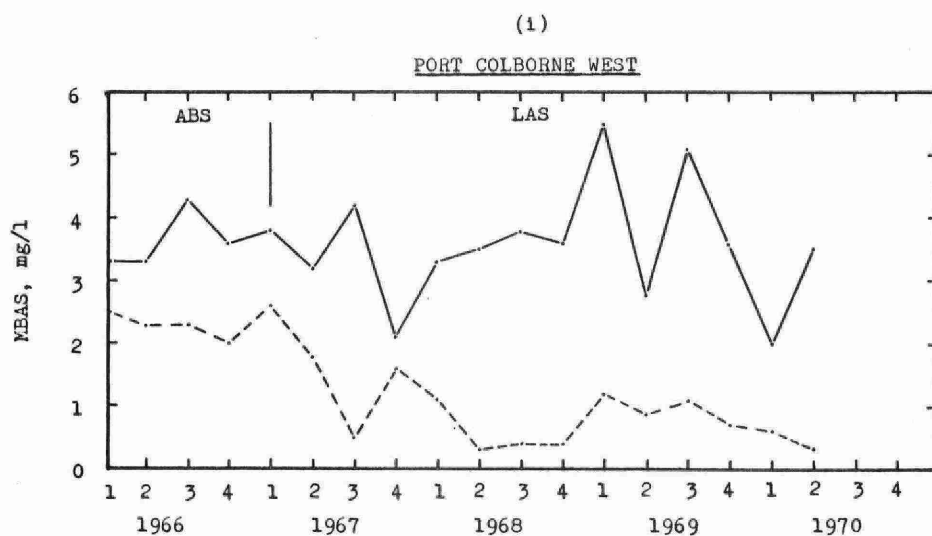
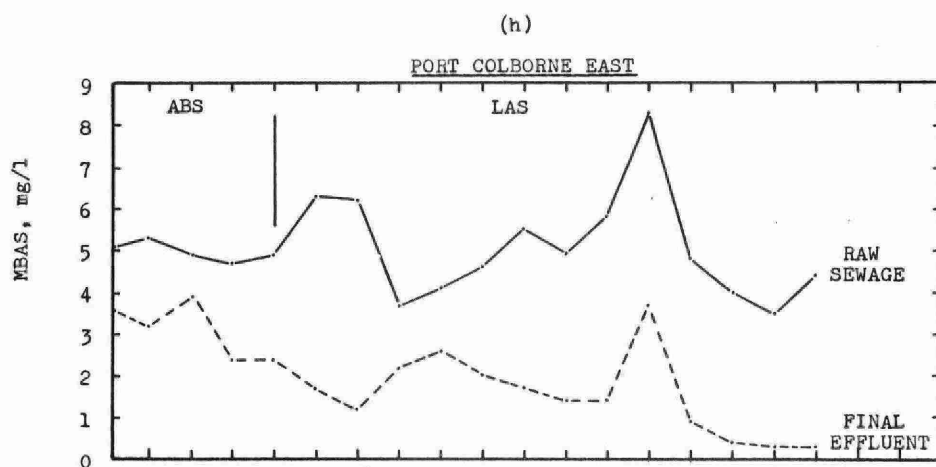
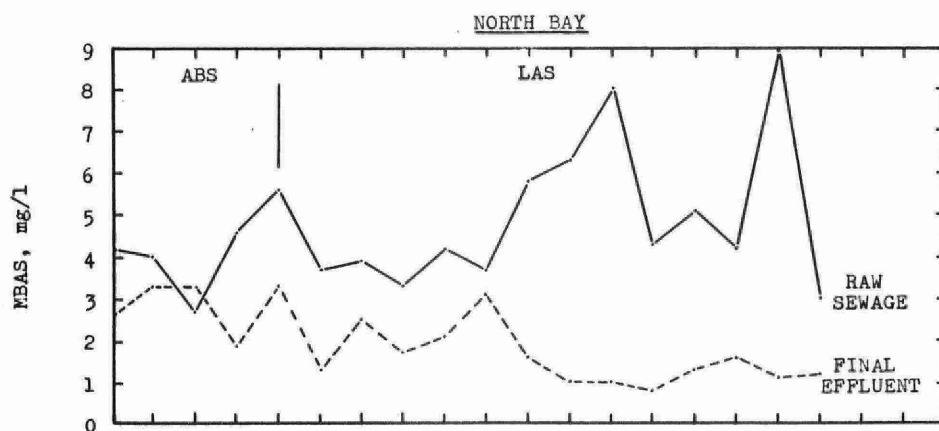
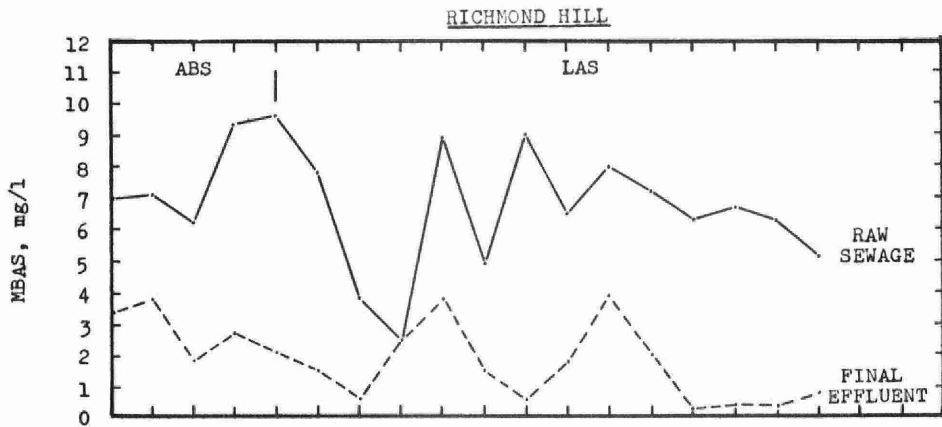
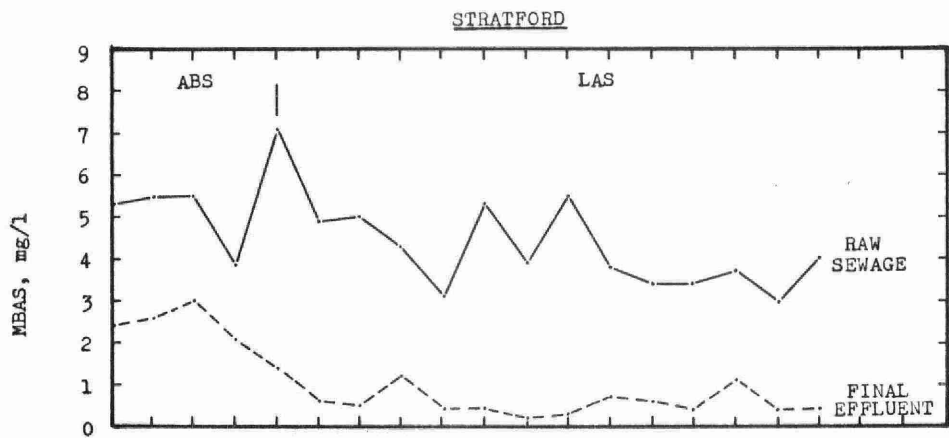


FIGURE 3. QUARTERLY MBAS CONCENTRATIONS IN RAW SEWAGE
AND FINAL EFFLUENT

Cont....



(k)



(l)

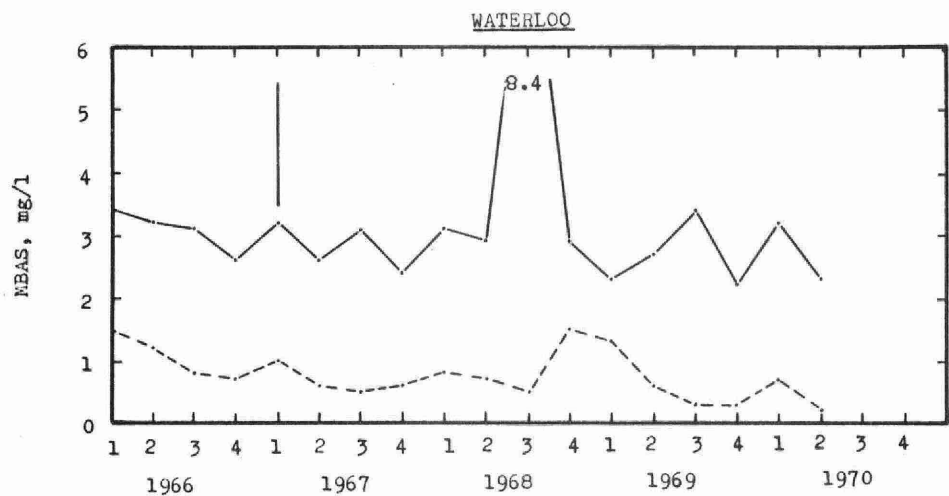


FIGURE 3. QUARTERLY MBAS CONCENTRATIONS IN RAW SEWAGE
AND FINAL EFFLUENT

Cont....

TABLE I
MUNICIPAL WPCP INCLUDED IN STUDY

MUNICIPALITY WPCP	TYPE OF TREATMENT ¹	DESIGN POPULATION	POPULATION SERVED (W&PC) ²	DESIGN FLOW (MGD)	AVERAGE FLOW 1969 (MGD)	1969 MBAS LOADING (LB/CAP/YR)
BURLINGTON						
-DRURY LANE	CAS	30,000		2.5	1.8	--
-ELIZABETH GARDENS	CAS	7,500	65,000	0.75	1.01	--
-SKYWAY	EA	35,000		3.125 ⁴	3.46	--
KINGSTON TWP.	CAS	10,000	6,000	1.0	0.911	49
KITCHENER	CAS	100,000	108,000	11.0	10.8	12
SOUTH PEEL						
-LAKEVIEW	CAS	100,000	100,000 ³	10.0	13.5	12
NORTH BAY	CAS	50,000	36,000	4.0	5.16	17
PORT COLBORNE						
-EAST	MAS	8,500	17,500 ³	0.85	1.45	--
-WEST	CAS	9,000		0.9	1.15	--
RICHMOND HILL	CAS	16,000	20,000	1.6	1.99	15
STRATFORD	CAS	30,000	24,000	4.0	3.26	13
WATERLOO	CAS	20,000	32,000	4.0	5.61	13

NOTE: ¹ CAS = Conventional Activated Sludge
 EA = Extended Aeration
 MAS = Modified Activated Sludge Without Primary Treatment
² W&PC = Water Pollution Control Directory: 1970-71
³ OWRC = 1966-67 Plant Operating Records
⁴ Design flow increased to 6.0 MGD effective March, 1970

TABLE II

MBAS CONCENTRATIONS IN RAW SEWAGE AND FINAL EFFLUENT

(a)

BURLINGTON-DRURY LANE WPCP

	BEFORE CHANGEOVER		AFTER CHANGEOVER	
	RAW SEWAGE	FINAL EFFLUENT	RAW SEWAGE	FINAL EFFLUENT
MEAN	6.5 MG/L	2.4 MG/L	6.3 MG/L	0.7 MG/L
STAN. DEV.	3.8 MG/L	0.9 MG/L	2.9 MG/L	1.0 MG/L
UPPER LIMIT	8.5 MG/L	2.7 MG/L	7.0 MG/L	0.9 MG/L
LOWER LIMIT	5.7 MG/L	2.1 MG/L	5.6 MG/L	0.4 MG/L
NUMBER OF OBSERVATIONS	31	31	70	67

(b)

BURLINGTON-ELIZABETH GARDENS WPCP

	BEFORE CHANGEOVER		AFTER CHANGEOVER	
	RAW SEWAGE	FINAL EFFLUENT	RAW SEWAGE	FINAL EFFLUENT
MEAN	8.0 MG/L	3.1 MG/L	6.8 MG/L	0.9 MG/L
STAN. DEV.	3.7 MG/L	1.2 MG/L	3.5 MG/L	2.1 MG/L
UPPER LIMIT	9.4 MG/L	3.7 MG/L	7.7 MG/L	1.4 MG/L
LOWER LIMIT	6.6 MG/L	2.8 MG/L	6.3 MG/L	0.4 MG/L
NUMBER OF OBSERVATIONS	29	29	73	67

(c)

BURLINGTON-SKYWAY WPCP

	BEFORE CHANGEOVER		AFTER CHANGEOVER	
	RAW SEWAGE	FINAL EFFLUENT	RAW SEWAGE	FINAL EFFLUENT
MEAN	4.3 MG/L	0.6 MG/L	3.5 MG/L	0.4 MG/L
STAN. DEV.	1.7 MG/L	0.3 MG/L	2.0 MG/L	0.5 MG/L
UPPER LIMIT	5.0 MG/L	0.7 MG/L	4.0 MG/L	0.5 MG/L
LOWER LIMIT	3.8 MG/L	0.5 MG/L	3.1 MG/L	0.3 MG/L
NUMBER OF OBSERVATIONS	29	29	69	68

Cont....

TABLE II (cont'd)

MBAS CONCENTRATIONS IN RAW SEWAGE AND FINAL EFFLUENT

(d)

KINGSTON TWP. WPCP

	BEFORE CHANGEOVER		AFTER CHANGEOVER	
	RAW SEWAGE	FINAL EFFLUENT	RAW SEWAGE	FINAL EFFLUENT
MEAN	4.9 MG/L	1.8 MG/L	9.7 MG/L	0.6 MG/L
STAN. DEV.	2.4 MG/L	1.5 MG/L	10.7 MG/L	0.6 MG/L
UPPER LIMIT	6.2 MG/L	2.6 MG/L	12.7 MG/L	0.8 MG/L
LOWER LIMIT	3.7 MG/L	1.1 MG/L	6.8 MG/L	0.4 MG/L
NUMBER OF OBSERVATIONS	17	17	53	54

(e)

KITCHENER WPCP

	BEFORE CHANGEOVER		AFTER CHANGEOVER	
	RAW SEWAGE	FINAL EFFLUENT	RAW SEWAGE	FINAL EFFLUENT
MEAN	4.5 MG/L	2.9 MG/L	4.4 MG/L	0.6 MG/L
STAN. DEV.	0.8 MG/L	1.7 MG/L	1.8 MG/L	0.4 MG/L
UPPER LIMIT	4.7 MG/L	3.6 MG/L	5.0 MG/L	0.8 MG/L
LOWER LIMIT	4.0 MG/L	2.1 MG/L	3.8 MG/L	0.5 MG/L
NUMBER OF OBSERVATIONS	20	21	40	40

(f)

SOUTH PEEL-LAKEVIEW WPCP

	BEFORE CHANGEOVER		AFTER CHANGEOVER	
	RAW SEWAGE	FINAL EFFLUENT	RAW SEWAGE	FINAL EFFLUENT
MEAN	5.0 MG/L	3.7 MG/L	4.2 MG/L	1.6 MG/L
STAN. DEV.	1.5 MG/L	1.1 MG/L	1.7 MG/L	0.9 MG/L
UPPER LIMIT	5.4 MG/L	3.9 MG/L	4.6 MG/L	1.8 MG/L
LOWER LIMIT	4.7 MG/L	3.3 MG/L	3.9 MG/L	0.4 MG/L
NUMBER OF OBSERVATIONS	62	62	79	80

Cont....

MBAS CONCENTRATIONS IN RAW SEWAGE AND FINAL EFFLUENT

(g)

NORTH BAY WPCP

	BEFORE CHANGEOVER		AFTER CHANGEOVER	
	RAW SEWAGE	FINAL EFFLUENT	RAW SEWAGE	FINAL EFFLUENT
MEAN	4.1 MG/L	3.0 MG/L	4.7 MG/L	1.5 MG/L
STAN. DEV.	2.4 MG/L	0.8 MG/L	2.7 MG/L	1.1 MG/L
UPPER LIMIT	5.4 MG/L	3.5 MG/L	5.5 MG/L	1.9 MG/L
LOWER LIMIT	3.1 MG/L	2.7 MG/L	3.8 MG/L	1.2 MG/L
NUMBER OF OBSERVATIONS	19	19	42	41

(h)

PORT COLBORNE-EAST WPCP

	BEFORE CHANGEOVER		AFTER CHANGEOVER	
	RAW SEWAGE	FINAL EFFLUENT	RAW SEWAGE	FINAL EFFLUENT
MEAN	5.0 MG/L	3.1 MG/L	5.0 MG/L	1.4 MG/L
STAN. DEV.	1.3 MG/L	1.2 MG/L	2.7 MG/L	1.2 MG/L
UPPER LIMIT	5.3 MG/L	3.5 MG/L	5.6 MG/L	1.7 MG/L
LOWER LIMIT	4.6 MG/L	2.8 MG/L	4.4 MG/L	1.1 MG/L
NUMBER OF OBSERVATIONS	48	49	82	76

(i)

PORT COLBORNE-WEST WPCP

	BEFORE CHANGEOVER		AFTER CHANGEOVER	
	RAW SEWAGE	FINAL EFFLUENT	RAW SEWAGE	FINAL EFFLUENT
MEAN	3.0 MG/L	2.3 MG/L	3.6 MG/L	0.8 MG/L
STAN. DEV.	1.2 MG/L	0.7 MG/L	1.7 MG/L	1.0 MG/L
UPPER LIMIT	4.1 MG/L	2.5 MG/L	4.0 MG/L	1.0 MG/L
LOWER LIMIT	3.3 MG/L	2.1 MG/L	3.2 MG/L	0.6 MG/L
NUMBER OF OBSERVATIONS	47	47	81	81

Cont.....

TABLE II (cont'd)

MBAS CONCENTRATIONS IN RAW SEWAGE AND FINAL EFFLUENT

(j)

RICHMOND HILL WPCP

	BEFORE CHANGEOVER		AFTER CHANGEOVER	
	RAW SEWAGE	FINAL EFFLUENT	RAW SEWAGE	FINAL EFFLUENT
MEAN	8.5 MG/L	3.0 MG/L	6.3 MG/L	1.5 MG/L
STAN. DEV.	3.5 MG/L	0.9 MG/L	3.0 MG/L	1.3 MG/L
UPPER LIMIT	10.9 MG/L	3.6 MG/L	7.2 MG/L	1.9 MG/L
LOWER LIMIT	6.5 MG/L	2.4 MG/L	5.4 MG/L	1.1 MG/L
NUMBER OF OBSERVATIONS	12	12	44	42

(k)

STRATFORD WPCP

	BEFORE CHANGEOVER		AFTER CHANGEOVER	
	RAW SEWAGE	FINAL EFFLUENT	RAW SEWAGE	FINAL EFFLUENT
MEAN	5.5 MG/L	2.2 MG/L	4.4 MG/L	0.6 MG/L
STAN. DEV.	3.0 MG/L	0.7 MG/L	2.1 MG/L	0.5 MG/L
UPPER LIMIT	6.7 MG/L	2.5 MG/L	4.9 MG/L	0.7 MG/L
LOWER LIMIT	4.5 MG/L	2.0 MG/L	3.8 MG/L	0.4 MG/L
NUMBER OF OBSERVATIONS	32	32	59	60

(l)

WATERLOO WPCP

	BEFORE CHANGEOVER		AFTER CHANGEOVER	
	RAW SEWAGE	FINAL EFFLUENT	RAW SEWAGE	FINAL EFFLUENT
MEAN	3.2 MG/L	1.1 MG/L	3.1 MG/L	0.8 MG/L
STAN. DEV.	1.3 MG/L	0.5 MG/L	2.9 MG/L	1.0 MG/L
UPPER LIMIT	3.6 MG/L	1.2 MG/L	3.7 MG/L	1.0 MG/L
LOWER LIMIT	2.9 MG/L	0.9 MG/L	2.5 MG/L	0.6 MG/L
NUMBER OF OBSERVATIONS	59	59	88	87

TABLE III

QUARTERLY AVERAGE BOD OF RAW SEWAGE AND FINAL EFFLUENT (mg/l)

YEAR QUARTER	BURLINGTON- DRURY LANE		BURLINGTON- ELIZABETH GARDENS		BURLINGTON-SKYWAY		KINGSTON TWP.		KITCHENER		SOUTH PEEL- LAKEVIEW	
	RAW SEWAGE	FINAL EFFLUENT	RAW SEWAGE	FINAL EFFLUENT	RAW SEWAGE	FINAL EFFLUENT	RAW SEWAGE	FINAL EFFLUENT	RAW SEWAGE	FINAL EFFLUENT	RAW SEWAGE	FINAL EFFLUENT
1966												
1	164	9	98	17	150	6	156	16	236	16	227	49
2	320	7	137	17	180	6	241	15	223	14	305	54
3	260	9	79	19	266	4	192	19	233	13	244	28
4	236	30	125	28	131	13	117	9	228	14	302	36
1967												
1	203	22	116	19	71	14	101	11	281	18	205	31
2	140	8	68	14	75	15	427	11	163	9	169	28
3	329	6	99	12	119	6	112	12	222	16	181	10
4	216	11	104	15	193	9	335	8	242	12	283	30
1968												
1	296	16	107	13	85	10	552	7	245	13	232	37
2	263	9	130	9	155	9	201	10	262	17	374	49
3	331	22	127	20	97	8	183	16	224	19	265	14
4	245	15	117	9	105	7	833	7	478	22	358	45
1969												
1	200	14	134	8	125	13	998	46	363	17	240	20
2	168	8	99	7	144	10	330	12	207	13	235	39
3	265	8	143	9	123	6	205	11	236	24	215	23
4	237	17	145	18	333	26	176	26	210	22	385	38
1970												
1	180	14	113	24	146	15	473	31	222	20	313	71
2	229	12	112	16	214	9	133	17	230	23	258	84

Cont.....

TABLE III (cont'd)

QUARTERLY AVERAGE BOD OF RAW SEWAGE AND FINAL EFFLUENTS (mg/l)

YEAR QUARTER	NORTH BAY		PORT COLBOURNE-EAST		PORT COLBOURNE-WEST		RICHMOND HILL		STRATFORD		WATERLOO	
	RAW SEWAGE	FINAL EFFLUENT	RAW SEWAGE	FINAL EFFLUENT	RAW SEWAGE	FINAL EFFLUENT	RAW SEWAGE	FINAL EFFLUENT	RAW SEWAGE	FINAL EFFLUENT	RAW SEWAGE	FINAL EFFLUENT
1966												
1	98	15	185	19	67	6	153	20	192	6	364	31
2	98	15	82	15	64	8	227	16	156	8	318	26
3	121	12	82	21	79	9	197	6	577	13	280	13
4	133	15	98	26	67	9	157	12	259	15	299	26
1967												
1	183	8.5	91	19	67	8	117	13	407	7	304	22
2	186	16	106	11	69	14	177	15	199	7	276	21
3	126	25	140	11	107	18	149	7	154	11	317	18
4	138	25	102	21	67	8	148	19	127	11	258	15
1968												
1	153	26	75	30	79	8	186	43	80	7	356	32
2	140	39	125	17	71	5	134	14	280	8	318	46
3	146	23	80	19	76	18	139	26	125	13	NA*	NA
4	270	8	96	14	75	14	163	18	431	4	NA	NA
1969												
1	175	6	142	13	82	12	133	20	99	14	350	14
2	99	6	134	16	65	16	103	23	125	6	320	13
3	95	27	105	6	95	8	129	6	84	8	326	15
4	133	32	204	8	83	18	100	6	125	10	92	23
1970												
1	205	35	62	9	75	7	138	18	200	5	290	30
2	88	36	72	10	68	6	89	15	190	8	347	24

NOTE: * Not Available

TABLE IV

QUARTERLY AVERAGE SUSPENDED SOLIDS OF RAW SEWAGE AND FINAL EFFLUENTS (mg/l)

YEAR QUARTER	BURLINGTON- DRURY LANE		BURLINGTON- ELIZABETH GARDENS		BURLINGTON-SKYWAY		KINGSTON TWP.		KITCHENER		SOUTH PEEL- LAKEVIEW	
	RAW SEWAGE	FINAL EFFLUENTS	RAW SEWAGE	FINAL EFFLUENT	RAW SEWAGE	FINAL EFFLUENT	RAW SEWAGE	FINAL EFFLUENT	RAW SEWAGE	FINAL EFFLUENT	RAW SEWAGE	FINAL EFFLUENT
1966												
1	230	7	130	10	149	8	208	7	421	23	304	71
2	370	8	174	13	169	10	257	16	273	14	328	77
3	317	12	159	7	338	3	218	46	358	24	486	47
4	322	10	137	8	180	13	176	5	308	12	304	87
1967												
1	335	8	114	15	119	7	309	13	261	15	268	73
2	227	10	98	10	103	7	163	12	270	13	275	105
3	518	12	190	10	174	7	161	15	272	15	271	16
4	864	9	95	11	225	10	215	7	290	13	349	27
11968												
1	535	10	107	13	86	17	561	18	283	16	317	42
2	489	7	130	9	134	23	654	6	298	15	354	46
3	346	11	127	20	101	10	566	20	323	16	285	24
4	216	10	117	9	111	6	783	16	366	39	326	50
1969												
1	358	13	167	10	162	17	1198	118	360	20	280	30
2	237	12	90	10	165	9	706	24	313	20	255	47
3	346	12	158	8	186	10	505	15	343	13	273	30
4	205	20	184	11	433	10	227	12	277	18	200	60
1970												
1	314	18	130	20	156	13	473	31	255	13	295	89
2	331	20	106	11	206	9	133	17	270	15	290	91

cont.....

TABLE IV (Cont'd)

QUARTERLY AVERAGE SUSPENDED SOLIDS OF RAW SEWAGE AND FINAL EFFLUENTS (mg/l)

YEAR QUARTER	NORTH BAY		PORT COLBOURNE-EAST		PORT COLBOURNE-WEST		RICHMOND HILL		STRATFORD		WATERLOO	
	RAW SEWAGE	FINAL EFFLUENT	RAW SEWAGE	FINAL EFFLUENT	RAW SEWAGE	FINAL EFFLUENT	RAW SEWAGE	FINAL EFFLUENT	RAW SEWAGE	FINAL EFFLUENT	RAW SEWAGE	FINAL EFFLUENT
1966												
1	203	38	210	29	81	9	219	18	176	6	231	31
2	143	17	110	18	61	5	181	10	243	13	226	25
3	174	23	119	27	119	7	296	9	480	6	222	17
4	139	15	102	16	73	5	299	15	240	7	243	34
1967												
1	218	20	152	25	89	7	158	34	351	11	262	22
2	228	31	187	15	82	16	224	14	238	7	305	24
3	264	41	206	16	112	8	255	9	204	9	342	20
4	192	31	155	25	109	7	284	9	172	12	229	13
1968												
1	293	31	91	35	56	6	291	24	117	11	262	38
2	193	28	216	29	113	10	200	9	356	15	249	59
3	249	38	126	24	82	9	159	16	185	8	NA	NA
4	188	39	187	21	76	11	274	15	209	11	NA	NA
1969												
1	200	8	228	22	78	10	200	20	182	11	265	25
2	202	13	265	26	78	29	133	17	172	11	237	27
3	296	52	192	8	111	8	164	5	114	8	256	16
4	140	53	224	55	104	29	89	20	270	13	248	20
1970												
1	258	40	94	19	91	14	191	23	232	13	218	45
2	220	30	103	20	89	7	173	16	246	9	343	23

TABLE V

EFFECT OF LOADING PARAMETERS ON MBAS REDUCTION BY THE ACTIVATED SLUDGE PROCESS

MUNICIPALITY WPCP DATE	FLOW (MGD)		AERATION TIME (HRS)	MLSS (MG/L)	BOD (MG/L)		SS (MG/L)		ANIONIC DETERGENT	MBAS (MG/L)		AVERAGE PERCENT REMOVAL		
	DESIGN	AVERAGE			RAW SEWAGE	FINAL EFFLUENT	RAW SEWAGE	FINAL EFFLUENT		RAW SEWAGE	FINAL EFFLUENT	BOD	SS	MBAS
BURLINGTON- DRURY LANE														
Jan 66 - Mar 67	2.5	1.6	9.4	2210	230	15	309	9	ABS	6.5	2.4	93	97	63
Apr 68 - Dec 68		1.6	9.4	3130	221	9	519	10	LAS	5.5	0.8	96	98	85
Jan 68 - Dec 68		2.1	7.2	1880	282	15	395	10	LAS	7.4	0.8	95	97	89
Jan 69 - Dec 69		1.8	8.4	2007	212	11	298	13	LAS	5.3	0.5	95	96	91
Jan 70 - June 70		2.28	6.7	2563	208	13	324	19	LAS	6.4	0.3	94	94	95
BURLINGTON- ELIZABETH GARDENS														
Jan 66 - Mar 67	0.75	0.88	6.1	1560	112	20	125	10	ABS	8.0	3.1	82	92	61
Apr 67 - Dec 67		1.05	5.1	1520	89	14	124	11	LAS	5.9	1.8	84	91	69
Jan 68 - Dec 68		1.06	5.0	2050	121	13	127	13	LAS	6.6	0.6	89	90	91
Jan 69 - Dec 69		1.01	5.3	2034	130	10	148	10	LAS	7.6	0.6	92	93	92
Jan 70 - June 70		1.24	4.3	2554	113	19	116	15	LAS	7.4	0.5	83	87	94
BURLINGTON- SKYWAY														
Jan 66 - Dec 67	3.125	3.02	21.8	5990	155	8	186	8	ABS	4.3	0.6	95	96	86
Apr 67 - Dec 67		4.14	15.9	5550	118	10	182	8	LAS	2.8	0.4	92	96	86
Jan 68 - Dec 68		3.75	17.5	4300	109	8	110	14	LAS	3.9	0.4	93	87	90
Jan 69 - Dec 69		3.46	19.0	3967	161	12	213	12	LAS	3.4	0.4	92	94	89
Jan 70 - June 70	6.0	3.52	-	3514	185	11	185	10	LAS	3.7	0.2	94	94	95

Cont.....

TABLE V (Cont'd)

EFFECT OF LOADING PARAMETERS ON MBAS REDUCTION IN ACTIVATED SLUDGE PROCESS

MUNICIPALITY WPCP DATE	FLOW (MGD)		AERATION		BOD (MG/L)		SS (MG/L)		ANIONIC DETERGENT	MBAS (MG/L)		AVERAGE PERCENT REMOVAL		
	DESIGN	AVERAGE	TIME (HRS)	MLSS (MG/L)	RAW SEWAGE	FINAL EFFLUENT	RAW SEWAGE	FINAL EFFLUENT		RAW SEWAGE	FINAL EFFLUENT	BOD	SS	MBAS
KINGSTON TWP.														
Jan 66 - Mar 67	1.0	0.603	8.7	1840	158	14	233	16	ABS	4.9	1.8	91	93	63
Apr 67 - Dec 67		0.749	7.0	3280	271	10	182	11	LAS	6.5	1.1	96	97	83
Jan 68 - Dec 68		0.816	6.4	2220	575	35	656	15	LAS	14	0.5	94	98	96
Jan 69 - Dec 69		0.911	5.8	2018	420	24	645	41	LAS	13	0.6	94	94	95
Jan 70 - June 70		1.132	4.6	1837	196	23	345	19	LAS	4.5	0.5	89	95	89
KITCHENER														
Jan 66 - Mar 67	10.1	10.2	6.0	2680	246	15	323	18	ABS	4.5	2.9	94	94	35
Apr 67 - Dec 67		11.1	5.5	2550	207	12	276	13	LAS	3.2	1.0	94	95	69
Jan 68 - Dec 68	11.0	10.5	7.3	2560	307	18	316	21	LAS	4.2	0.6	94	93	86
Jan 69 - Dec 69		10.8	7.1	2400	251	19	326	17	LAS	5.2	0.6	92	95	89
Jan 70 - June 70		10.9	7.0	2630	224	21	261	13	LAS	4.7	0.4	91	95	91
SOUTH PEEL-- LAKEVIEW														
Jan 66 - Mar 67	5.0	8.43	3.6	1010	253	39	333	72	ABS	5.0	3.7	85	78	26
Apr 67 - Dec 67		10.1	3.0	1320	174	20	273	62	LAS	4.0	1.5	89	80	62
Jan 68 - Dec 68	10.0	11.7	5.1	1660	289	35	320	40	LAS	4.5	1.6	88	88	64
Jan 69 - Dec 69		13.5	4.4	1460	256	28	276	43	LAS	4.1	1.4	89	85	66
Jan 70 - June 70		13.6	4.4	1370	284	77	293	88	LAS	4.9	2.3	73	70	54

Cont.....

TABLE V (Cont'd)

EFFECT OF LOADING PARAMETERS ON MBAS REDUCTION IN ACTIVATED SLUDGE PROCESS

MUNICIPALITY WPCP DATE	FLOW (MGD)		AERATION TIME (HRS)	MLSS (MG/L)	BOD (MG/L)		SS (MG/L)		ANIONIC DETERGENT	MBAS (MG/L)		AVERAGE PERCENT REMOVAL		
	DESIGN	AVERAGE			RAW SEWAGE	FINAL EFFLUENT	RAW SEWAGE	FINAL EFFLUENT		RAW SEWAGE	FINAL EFFLUENT	BOD	SS	MBAS
NORTH BAY														
Jan 66 - Mar 67	4.0	3.88	5.4	1200	123	13	176	21	ABS	4.1	3.0	89	88	27
Apr 67 - Dec 67		3.79	5.6	890	156	21	225	33	LAS	3.7	1.8	87	85	51
Jan 68 - Dec 68		4.06	5.2	1270	174	22	222	32	LAS	5.3	1.7	87	86	68
Jan 69 - Dec 69		5.16	4.1	1360	117	20	234	34	LAS	5.2	1.3	83	86	76
Jan 70 - June 70		5.37	3.9	1350	128	36	233	33	LAS	4.2	1.2	72	86	72
PORT COLBORNE - EAST														
Jan 66 - Mar 67	0.85	0.93	5.5	2500	112	20	144	23	ABS	5.0	3.1	82	84	38
Apr 67 - Dec 67		1.12	4.6	2380	109	13	171	17	LAS	5.3	1.7	88	90	68
Jan 68 - Dec 68		1.39	3.7	2220	95	20	159	27	LAS	4.8	1.9	79	83	60
Jan 69 - Dec 69		1.45	3.5	2756	146	9	228	27	LAS	5.3	1.4	94	88	75
Jan 70 - June 70		1.59	3.2	2290	66	9	98	12	LAS	3.9	0.3	86	88	92
PORT COLBORNE - WEST														
Jan 66 - Mar 67	0.9	0.99	6.4	1290	68	9	82	7	ABS	3.6	2.3	87	91	36
Apr 67 - Dec 67		1.06	6.0	1550	80	15	101	10	LAS	3.1	1.4	81	90	55
Jan 68 - Dec 68		1.16	5.5	1450	75	11	82	9	LAS	3.5	0.5	85	89	86
Jan 69 - Dec 69		1.15	5.5	1580	81	13	92	17	LAS	4.4	1.0	84	82	77
Jan 70 - June 70		1.19	5.3	1150	72	6	90	10	LAS	2.8	0.5	91	89	82

Cont.....

TABLE V (Cont'd)

EFFECT OF LOADING PARAMETERS ON MBAS REDUCTION IN ACTIVATED SLUDGE PROCESS

MUNICIPALITY WPCP DATE	FLOW (MGD)		AERATION TIME (HRS)	MLSS (MG/L)	BOD (MG/L)		SS (MG/L)		ANIONIC DETERGENT	MBAS (MG/L)		AVERAGE PERCENT REMOVAL		
	DESIGN	AVERAGE			RAW SEWAGE	FINAL EFFLUENT	RAW SEWAGE	FINAL EFFLUENT		RAW SEWAGE	FINAL EFFLUENT	BOD	SS	MBAS
RICHMOND HILL														
Jan 66 - Mar 67	1.6	1.69	5.5	1840	169	13	225	18	ABS	8.5	3.0	92	92	65
Apr 67 - Dec 67		1.68	5.5	1480	160	15	252	11	LAS	5.0	1.7	91	96	66
Jan 68 - Dec 68		1.92	4.8	960	156	26	232	16	LAS	7.0	1.7	83	93	77
Jan 69 - Dec 69		1.99	4.7	1130	121	14	167	14	LAS	7.0	1.9	88	92	73
Jan 70 - June 70		2.11	4.4	1260	148	16	182	19	LAS	5.8	1.1	89	90	82
STRATFORD														
Jan 66 - Mar 67	4.0	3.11	6.2	2330	288	9	282	9	ABS	5.5	2.2	97	97	60
Apr 67 - Dec 67		3.98	4.9	2320	162	9	204	9	LAS	4.8	0.8	94	96	83
Jan 68 - Dec 68		3.46	5.6	2350	281	7	302	11	LAS	4.7	0.3	98	96	94
Jan 69 - Dec 69		3.26	5.9	2340	108	9	170	10	LAS	3.6	0.6	92	94	83
Jan 70 - June 70		3.55	5.4	2070	196	6	238	11	LAS	3.4	0.4	97	95	88
WATERLOO														
Jan 66 - Mar 67	4.0	3.26	8.8	2320	312	24	238	26	ABS	3.2	1.1	92	89	66
Apr 67 - Dec 67		4.04	7.1	2310	283	18	292	19	LAS	2.7	0.6	94	93	78
Jan 68 - Dec 68		4.04	7.1	2760	342	38	257	46	LAS	3.1	0.8	89	82	74
Jan 69 - Dec 69		5.61	5.1	2530	323	16	251	21	LAS	2.8	0.5	95	92	81
Jan 70 - June 70		5.04	5.7	2720	318	27	293	22	LAS	2.6	0.4	92	89	83



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